UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
WASHINGTON, D. C.
H. H. BENNETT, CHIEF

ADVANCE REPORT

on the

SEDIMENTATION SURVEY OF BURLINGTON RESERVOIR

BURLINGTON, NORTH CAROLINA

April 16 to May 21, 1938

by

Mark P. Connaughton and Jack L. Hough

Sedimentation Studies
Division of Research
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North Carolina Agricultural Experiment Station
Raleigh, N. C.
I. O. Schaub, Acting Director

ABSTRACT

The sedimentation survey of Burlington Reservoir was made as part of a Nation-wide study of rates and causes of reservoir silting, especially as influenced by soil erosion and land use.

Burlington Reservoir, the water supply for Burlington, Alamance County, N. C., is a channel-type 1,500-acre-foot reservoir on Stony Creek, a tributary of the Haw River. Its drainage basin, 105 square miles in area, lies on the Piedmont Upland and is characterized by undulating to strongly rolling topography and dominantly sandy loam soils developed on granitic rocks. Rather severe sheet erosion and occasional to frequent gullies have removed 50 to 75 percent of the topsoil from about three-fifths of the area. About 35 percent of the drainage area is cultivated, the principal crops being tobacco and corn; 50 percent is woodland; and 15 percent is abandoned land and pasture. Agriculture in this region dates from about 1750.

The reservoir sediment ranges from fine silt and clay near the dam to coarse sand and gravel at the upper end. Determinations on 11 samples gave an average dry weight of 63 pounds per cubic foot of sediment in place. Deposits in the lower basin average about 1 foot in thickness with little variation, but in the upper part of the lake the average depth at successive cross sections varies irregularly between 1 and 5 feet.

The bulk of the reservoir sediment has originated from rather severe sheet erosion that occurs over most of the drainage area, although a large part of the coarser sediment was traced to seriously gullied areas. Calculations based on (1) the total volume of soil moved from place in the drainage area, as computed from erosion data, and (2) the total period of agricultural activity (about 200 years) indicate that the average time required for erosion of 1 inch of soil in the area as a whole is about 60 years. In contrast, the volume of sediment in the reservoir indicates a minimum net removal from the watershed of 1 inch of soil in 530 years. This wide discrepancy is explained by colluvial and alluvial deposition in the drainage area and bypassing of sediment through the reservoir.

The survey revealed that 163 acre-feet (263,000 cubic yards) of sediment had accumulated in the reservoir at an average rate of nearly 11 cubic feet per year per acre of drainage area, entailing a loss of original storage of 1.1 percent per year, or about 11

percent to the date of survey. As sediment is being contributed from areas of moderate to severe sheet and gully erosion throughout the drainage basin, the only feasible method of protecting the reservoir from continued excessive silting is through the widespread application of erosion-control measures, such as are now in effect on much of the land within the Stony Creek Soil Conservation Project which includes 64 percent of the area above the reservoir. In addition, measures to control the comparatively large volume of sediment temporarily lodged along the drainageways, and subject to ultimate transportation into the reservoir if not stabilized, are highly desirable.

INTRODUCTION

This report is one of a series of advance reports on reservoir silting investigations made by the Section of Sedimentation Studies, Division of Research, Soil Conservation Service. Each reservoir survey is a part of a Nation-wide study of the condition of American reservoirs with respect to storage reduction by silting. The ultimate objective of these studies is to determine the nature, rates, and causes of reservoir silting, in order to derive a practical index to (1) the useful-life expectancy of existing or contemplated reservoirs, and (2) differences and changes in regional erosion conditions as influenced both by natural factors and by land use.

The sedimentation survey of Burlington Reservoir was made during the period April 16 to May 21, 1938, by the Section of Sedimentation Studies, Division of Research, Soil Conservation Service. The survey party consisted of Leland H. Barnes, party chief, Mark P. Connaughton, party geologist, Alvin T. Talley, Nicholas C. Boogher, and Joseph Meisler. Preliminary data were secured by Alexis N. Garin of the Section of Economics of Soil Conservation, Division of Research. Preliminary examination and arrangements for the survey were made by Carl B. Brown of the Section of Sedimentation Studies. Studies of the lake sediment and an inspection of the drainage area were made by the writers.

Laboratory studies of the sediment samples were made under the direction of Jack L. Hough in the laboratories of the city filtration plant at High Point, N. C. Laboratory facilities were made available through the courtesy of the city of High Point.

The cooperation and assistance of the Burlington municipal officials, especially L. C. Lindberg, city engineer, and E. R. Thomas, director of public utilities, greatly facilitated the sedimentation survey of Burlington Reservoir. The city furnished

original maps of the lake, blueprints of the dam, and information on the history and cost of the reservoir. In addition, several boats were placed at the disposal of the party, and materials and labor were furnished for the construction of the concrete survey markers.

Members of the staff of the Stony Creek Soil Conservation Project (NC-4) of the Service, at Burlington, particularly H. N. Kelly, project manager, and Jacob A. Lutz, Jr., junior soil surveyor, assisted in the compilation of data on the drainage area.

G. W. Forster, head of the Department of Economics and Rural Sociology, North Carolina State College, advised and aided in economic studies related to the various reservoir-silting investigations carried out in North Carolina in the spring of 1938.

GENERAL INFORMATION

Location (fig. 1):

State: North Carolina.

County: Alamance.

Distance and direction from nearest city: The dam is 3 miles northeast of Burlington.

Drainage and backwater: Stony Creek, which flows one-half mile south from the dam to join the Haw River, a tributary of the Cape Fear River.

Ownership: City of Burlington.

Purpose: (1) Municipal and industrial water supply; (2) recreation.

Description of dam.

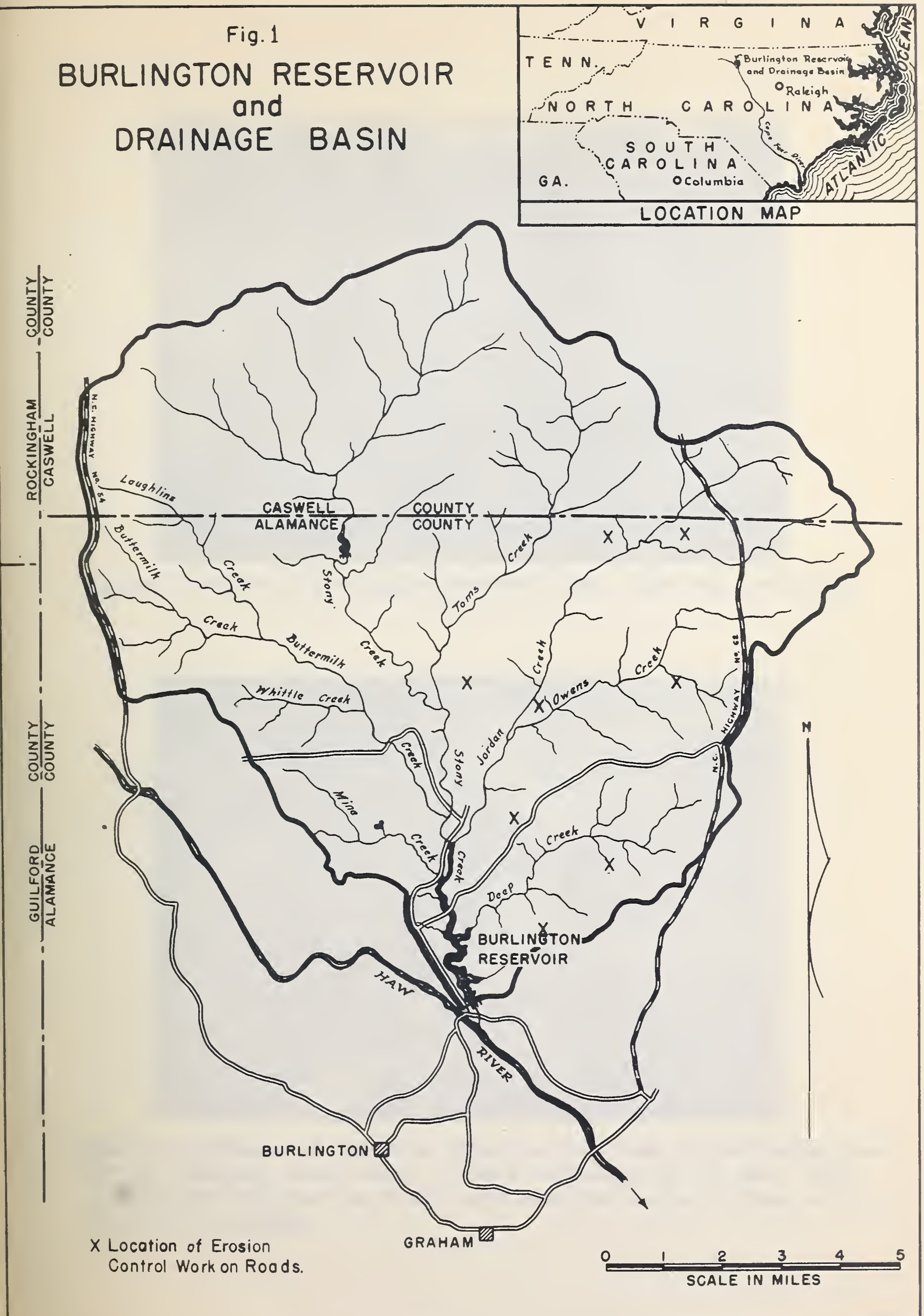
Burlington Reservoir is impounded by a cyclopean-masonry gravity-type dam (fig. 2) 456 feet long and 36 feet in maximum height above the stream bed. The top of the dam, at an assumed elevation of 62 feet (local datum), is 5 feet above spillway crest level. The upstream face of the dam is vertical and the downstream face has a slope of 1 1/2 to 1. The top width of the dam is 5 feet, and the bottom width is 24 feet in the bulkhead sections and 32 feet in the spillway section.

The ogee-shaped spillway section, beginning 200 feet from the west abutment, is 60 feet long and is adjoined on the east by an 80-foot flood spillway (fig. 2). The normal spillway crest is 31 feet above the stream channel, at elevation 57, and the flood spillway is 1 foot higher, at elevation 58. A small pump house, below the south end of the dam, houses a hydraulic turbine fed through a head race which is used approximately 6 months out of the year to pump water to the filter plant.

The total original cost of the development was approximately $318,000.

Fig. 1

BURLINGTON RESERVOIR and DRAINAGE BASIN



N-2309

<u>Date of completion of dam</u>: June 1928. At the time of the sedimentation survey the lake was 10 years old.

<u>Length of lake</u>: 3.66 miles from the dam to the head of backwater on Stony Creek. The Deep Creek arm is 0.49 mile long.

<u>Area of lake at spillway stage</u>: Originally 137 acres. Minor above-crest and lateral sedimentation had reduced this area to 136 acres at the date of survey.

Storage capacity to spillway level:	Acre-feet	
Original........................	1,488	(484,864,800 gals.)
At date of survey...............	1,325	(431,751,250 gals.)
Reduction by sedimentation.....	163	(53,113,550 gals.)

<u>General character of reservoir basin.</u>

The lake (fig. 4, following page 25) occupies a moderately winding, narrow basin extending generally northward from the dam. The reservoir is distinctly a channel type, with a relatively low capacity-inflow ratio. The width of the lake decreases fairly regularly from a maximum of 625 feet on range R2-R3, near the dam, to 95 feet on range R74-R75, just below the head of backwater.

The shore line is made moderately irregular in the lower reaches by a large number of small tributary valleys, but water is impounded on only one large tributary, Deep Creek, which enters the main basin from the east about 1.5 miles above the dam. The width of the Deep Creek arm decreases regularly from 300 feet at the mouth to about 20 feet near the head of backwater.

Slopes adjacent to the lake shore are gentle throughout the basin area. Practically the whole shore line is flanked by a dense growth of vegetation, mainly willows, alders, and honeysuckle. This vegetation, in addition to preventing wave erosion along the banks, has acted as a screen to stop much erosional debris washed from steep valley sides along the lake shores, and is therefore extremely valuable in controlling erosion and silting.

The submerged valley sides within the basin have an average inclination of 24 percent but range from 10 to 60 percent. Between the dam and range R58-R59 the submerged flood plain tends to be poorly defined and irregular, being rarely present on both sides of the channel at the same point. It ranges in width from 100 to 300 feet, averaging about 168 feet. Locally well-defined natural

levees border the submerged channel. The submerged stream channel, which follows a moderately winding course through the reservoir, has an average width of about 50 feet and a depth of 11 feet below the flood plain. The original gradient was 9.5 feet per mile from the head of backwater to range R1-R2 on Stony Creek, and 30.8 feet per mile from the head of backwater to range R34-R36 on Deep Creek.

Area of drainage basin: 105.2 square miles, or 67,334 acres, as determined by planimeter measurement of the map of the Stony Creek Soil Conservation Project in Alamance County (scale 1 inch to 2 miles) and of the Caswell County soil map (scale 1 inch to 1 mile).

General character of drainage basin.

Geology.--The area tributary to Burlington Reservoir lies within the Piedmont Upland section of the Piedmont province. Geologically, it lies within the outcrop area of the so-called "Carolina Igneous Belt", which occupies a nearly central position in the Piedmont Plateau in North Carolina and extends across the State from a point east of Danville, Va., southwestward into South Carolina. This area is composed principally of coarse-grained igneous rocks of two main types, granite and diorite, most of which exhibit gneissic or schistose structure to varying degrees. They are penetrated by dikes of granite, aplite, and basic igneous intrusive rocks, including some diabase dikes of late Triassic or Jurassic age.

The country rock in the vicinity of the reservoir is a biotite granite, somewhat gneissic, varying in color from nearly white to dark gray and in texture from moderately coarse- to fine-grained. Exposures at Altamahaw, just west of the drainage area, show a compact fine-grained dark-gray syenite porphyry. This rock probably underlies at least a part of the drainage area above Burlington Reservoir.

Bedrock is exposed within the drainage area in only a few small outcrops, being generally covered by a mantle of residual soil.

Topography and drainage.--The topography is undulating to strongly rolling, characterized by moderately broad interstream areas from which slopes break rather sharply near the streams. Geomorphically, the region in general is in a stage of maturity but shows some features characteristic of late youth, particularly in sections where small tributary streams are rapidly developing headward.

The drainage area constitutes part of a broad upland plain, maturely dissected by streams which have cut valleys 50 to 100 feet below the general surface. Stony Creek Mountain, in the north-central part of the area and just south of the Caswell County line, is a monadnock rising several hundred feet above the general upland level. The average slope in the drainage area is about 7 percent. Only 16 percent of the total area has slopes of more than 12 percent, according to preliminary calculations.

The drainage system is well-developed and dendritic (fig. 1). The principal streams are Jordan, Tom's, Stony, Buttermilk, and Deep Creeks. All the major streams have fairly broad valleys and comparatively steep gradients. At a point 6 miles above the head of the reservoir it was possible to estimate the gradient of Stony Creek in a reach several thousand feet long from the length of backwater above a 12-foot dam. This reach, which is believed to be fairly representative of Stony Creek above Burlington Reservoir, was found to have a gradient of about 18 feet per mile. Most of the valleys have well-defined but rather narrow flood plains. The main stream channel 2 miles above the lake is about 30 feet wide and 5 feet deep and contains a large amount of sand.

Soils.--Although soil maps are available for the whole watershed area,[1] they are too generalized to be of much present value. The major soil type is a sandy loam, although some clay loam is found. Approximately 64 percent of the watershed area, the portion in Alamance County, lies within the boundaries of the Stony Creek Soil Conservation Project. The soil series occurring in this section and their proportionate areas are given in the following tabulation. Final correlation of these soil types has not yet been made, and it is possible that the percentage of Wilkes soil, which is more or less confined to steep slopes, is too high.

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[1]Coffey, G. N., and Hearn, W. E. Soil Survey of Alamance County, North Carolina. U. S. Dept. Agr., Bur. Soils Field Oper. 1901, soil map, 1902.
Hearn, W. E., and Drane, F. P. Soil Survey of Caswell County, North Carolina. U. S. Dept. Agr., Bur. Soils Field Oper. 1908, soil map, 1910.

	Percent
Helena sandy loam	60.0
Wilkes sandy loam	22.4
Iredell sandy loam and loam	5.0
Appling sandy loam	4.0
Cecil sandy loam and clay loam	3.0
Congaree and meadow	4.0
Mecklenburg loam	1.0
Worsham sandy loam and silt loam	.5
Wehadkee silt loam	.1
Total drainage area	100.0

The soils of the upper part of the drainage area in Caswell County were classified[2] in the Iredell, Cecil, and Durham series, in order of relative abundance. In general the soils in the drainage area are comparatively shallow.

Erosion conditions.--Rather severe erosion prevails throughout the district. Detailed erosion data indicate that approximately three-fifths of the land in the drainage basin has lost 50 to 75 percent of its topsoil. Occasional to frequent gullies have developed, but few of these are very deep. There are occasional small areas of totally destroyed land. These areas have been generally retired from cultivation and tend to become stabilized by natural revegetation. Poorly constructed road ditches and unprotected borrow pits are contributing a measurable amount of the erosional debris (fig. 3).

Adequate data on erosion conditions in the Caswell County section of the watershed area are not available. Reconnaissance investigation of the area, however, indicated that the conditions in the Alamance County section, shown in the following tabulation, are fairly representative of the entire area.

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[2]See footnote 1, page 7.

	Percent
Alluvial and colluvial deposits............................	6.0
No apparent erosion..	20.0
Slight sheet erosion (less than 25 percent of topsoil removed)...	2.0
Moderate sheet erosion (25-50 percent of topsoil removed) and occasional gullies..........................	10.0
Moderately severe sheet erosion (50-75 percent of topsoil removed) and occasional to frequent gullies....	59.5
Severe to very severe sheet erosion (over 75 percent of topsoil and some subsoil removed) and occasional to frequent gullies....................................	2.0
Land totally destroyed by gullying.........................	.5
Total section..	100.0

Land use.--The watershed area lies within the so-called "Old Tobacco Belt." Early agriculture in the area, probably dating back to 1750, consisted of growing corn, wheat, and oats as the principal feed crops and tobacco as the principal cash crop. More livestock was raised in early periods than at present. Tobacco first became a main crop about 1860. After the Civil War much land was abandoned, some of which has not yet been entirely reclaimed for agriculture. Immediately after the war the production of grain crops decreased and tobacco became the important cash crop. Since then tobacco has remained the important cash crop (at present accounting for about 90 percent of the monetary farm income), but in recent years the trend has been toward a better balanced agricultural program.

Approximate figures on land use in the drainage area, based on actual records for the part within the Stony Creek Soil Conservation Project area, and on a reconnaissance of the Caswell County area, are given in the following tabulation:

	Percent
Cultivated land:	
Tobacco	9
Corn	10
Wheat and oats	6
Hay (permanent)	3
Lespedeza	5
Miscellaneous	2
Total	35
Woodland:	
Virgin, mainly hardwoods	20
Second growth, pines or mixtures	30
Total	50
Pasture	5
Abandoned	10
Total drainage area	100

The average size of farms in the drainage area is about 95 acres, individual farms ranging from 25 to 800 acres. Of the farm land, 94 percent is owner-operated, 5 percent is share-cropped, and 1 percent is occupied by cash renters.

Mean annual rainfall.

Records of the United States Weather Bureau at Graham, N. C., approximately 3.8 miles south of the dam, are as follows:

Period	Inches
1902-38	45.92
1928-38	46.44

During the period 1928-38 (i. e., the life of the lake), the annual rainfall ranged from 29.51 to 58.44 inches. Rainfall is most abundant during June, July, and August, but on the whole it is fairly well distributed throughout the year.

Draft on reservoir.

The average daily draft on the reservoir for the entire 10-year period of storage was about 1,444,000 gallons. Water consumption, however, showed a decided increase through the years, owing

mainly to increase in industrial usage. The average daily draft steadily increased from 1,057,000 gallons in 1931 to 2,079,000 gallons in 1937. This gradual increase in the volume of water used, together with wide fluctuations in the volume used industrially, has tended to obscure the normal increase in consumption during the summer season so characteristic of other water-supply reservoirs. Approximately 60 percent of the water treated is used industrially, mainly by textile-finishing plants. The greatest consumption for a 24-hour period was 3,058,000 gallons.

In addition to the draft created by domestic and industrial consumption, a large amount of water is wasted through the millrace that is used to operate the turbine about 6 months of each year. This loss is approximately five times the amount of water pumped into town for domestic consumption during a normal 1-year period.

METHOD OF SURVEY

Water and sediment volumes in Burlington Reservoir were determined by the range method of survey.[3] A triangulation system of 18 points was established by plane-table triangulation from a carefully measured base line 1,025.0 feet long. This triangulation network was carried upstream to a point 2,900 feet above the dam. Beyond this point the lake was too narrow and winding to justify triangulation, so from this point to the head of backwater horizontal control was provided by 28 stations established by plane table and stadia. The shore line at spillway level was transferred onto this triangulation and stadia-control net from aerial photographs of the lake taken in 1935. This was possible because the shore line had been changed very little prior to the date of photographing. Additional horizontal control, necessary to adjust the scale of the aerial photographs to agree with the scale of 1 inch to 200 feet used in the reservoir survey, was supplied by two chained and checked transit traverses tied into the reservoir network. These control base lines, 2,363 and 1,701 feet long, respectively, were measured between points in the field that were readily distinguishable on the aerial photographs. Slight adjustments in the shore line so plotted were made by remapping certain critical areas where the shore line was vague on the aerial photographs or where deposition prior to the date of photographing had

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[3] Eakin, H. H. Silting of Reservoirs. U. S. Dept. Agr. Tech. Bull. 524: 129-135, 1936.

altered the original shore line. Some remapping was also necessary to show the 1938 position of the shore line where it had been altered by sedimentation.

Adequate checking of the shore line at a number of points indicated that the above method gave results within the limits of accuracy of the survey. For the measurement of silt thickness and water depth 57 ranges were established across the reservoir at suitable positions. All range ends, cut-in stations, and base-line stations were permanently marked with iron pipe stamped with the station numbers and set in concrete.

The contact between the lake deposits and the underlying materials is sharp and easily identified except in the delta area. Over most of the lake bottom the underlying valley material is a gray fine sandy loam grading downward into a more compact sandy loam of lighter color and higher clay content. The surface layer of the pre-lake material contains a fair proportion of humus and a distinct rootlet zone at the surface. A yellowish-brown gritty clay loam occurs on the submerged valley slopes in a few places. Within the submerged channel, medium to coarse grayish-brown washed sand is the normal pre-lake material. In the Stony Creek delta area the normal pre-lake material consists of gray sandy silt loam on the submerged flood plains and bedrock in the channel. Here a buried rootlet zone and greater compaction proved very helpful in recognizing the pre-lake material in the absence of marked textural differences.

Eleven samples of lake sediment were taken from various parts of the lake. Two of these, one from each of the "ponded channel" sections, were composite samples collected by hand. The other nine, so spaced throughout the basin as to detect any lateral or longitudinal change in sediment type, were collected with a modified Trask coring tube.[4] This sampler consists of a 4-foot length of 1 1/2-inch galvanized iron pipe surmounted by a 1 1/2-inch vertical check valve and attached by a close nipple and reducer to a 4 1/2-foot length of 3/4-inch pipe. This assembly is attached to a rope by means of a T-joint and can be lowered and withdrawn in the same manner as the spud used in measuring sediment depths. Samples are obtained in 1 1/2-inch iron pipe nipples 4 inches long attached to the main 4-foot pipe by a collar. The nipples containing the sediment are removed from the sampler immediately after being withdrawn from the lake bottom and capped with threaded airtight iron covers for shipment to the laboratory. It is possible,

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[4]Trask, P. D. Oceanography and Oil Deposits. Natl. Research Council Bull. 61: 235-240, 1927.

with proper handling of this sampler, to obtain representative samples of all but very sandy sediment under varying conditions of compaction and depth below the surface of the deposits.

SEDIMENT DEPOSITS

In order to adequately discuss the sediment in Burlington Reservoir it is well to consider the lake basin as being made up of three distinct sections, each showing essentially uniform sedimentation conditions. These sections are as follows:

(1) A "lower basin" section, extending from the dam to range R44-R45 on Stony Creek and to range R86-R87 on Deep Creek (fig. 4).

(2) A "delta" section, extending from range R44-R45 to range R62-R63 on Stony Creek. With this section may be included the corresponding area on Deep Creek, extending from R86-R87 to range R92-R93.

(3) A "ponded channel" section, extending from range R62-R63 to the head of backwater on Stony Creek. This section also may be taken to include the similar area extending from range R92-R93 to the head of backwater on Deep Creek.

Distinctions between these three sections are brought out in the following discussion.

Character of Sediment

The sediment in Burlington Reservoir ranges in texture from fine silt and clay near the dam to coarse sand and gravel near the head of backwater. The finer sediment is confined mainly to the lower-basin section, and the sand to the ponded-channel section. The sediment in the delta section is generally a sandy silt but ranges from fine sand to fairly coarse silt. There is little lateral variation in texture in either the lower basin or the ponded-channel section, but in the delta section there is a normal progression from the submerged channel outward from coarse to medium sand in the channel, to sandy silt adjacent to the channel, to silt near the shores.

The color of the sediment ranges from buff to greenish buff in the lower basin, is fairly dark gray in the delta areas, and is generally grayish brown in the ponded-channel section. The organic content of the sediment is low in both the lower-basin and the ponded-channel sections but very high in the delta areas. The average organic content of the sediment in the two deltas may run as high as 40 percent. Local zones or lenses of highly organic material have an organic content of perhaps as much as 80 percent by volume. These zones, which may approach 2 feet in thickness, consist of accumulations of debris, mainly leafy matter. At a few points several of these layers were encountered in a vertical section, suggesting seasonal deposition. So rich in organic matter are these deltaic zones that any disturbance of the water (by high winds, the passage of a motorboat, etc.) evokes a very vigorous "bubbling" due to the release of marsh gas from the buried vegetal matter.

With the exception of minor deposits in restricted shallow-water areas, all the sediment is poorly compacted. Sediment at depths of less than 2 feet has been exposed to drying during periods of low water and has been rendered fairly compact.

Volume weights of the sediment samples were determined by two different methods. For finer-textured sediment, including samples 1 to 9, the moisture content and dry weight were determined for a small representative quantity of each of the samples. From these values, the porosity and weight per cubic foot were calculated by assuming that the density of the solid sediment was equal to that of quartz (165 pounds per cubic foot). These determinations were made by Jack L. Hough.

Volume weights of samples A and B, composed of medium to coarse well-sorted sand, were based on mechanical analyses made by Richard G. Grassy in the sediment laboratory of the Section of Sedimentation Studies at Greenville, S. C. From the median grain size of the samples, and data on the relationship of median grain size to porosity of sediments as taken from unpublished laboratory results on file in the Section, the average porosity of these samples was determined to be approximately 40 percent.

The location, depth relations, and dry weight per cubic foot of the sediment samples are listed in table 1.

Table 1.--Bottom-sediment samples from Burlington Reservoir

Sample No.	Location	Water depth	Silt thickness	Penetration[1]	Dry weight per cubic foot
	Lower basin	Feet	Feet	Feet	Pounds
1............	Range R4-R5, 350 feet from R5.....	27.2	3.7	1.5	48
2............	Range R5-R6, 190 feet from R5.....	13.4	.9	.5	45
3............	Range R32-R33, 200 feet from R33....	18.0	3.0	1.5	54
4............	Range R32-R33, 120 feet from R33....	3.0	1.0	.5	50
5............	Range R42-R43, 90 feet from R42....	6.2	.8	.6	63
Average....	....	......	....	......	52
	Delta section				
6............	Range 46-R47, 200 feet from R47....	16.3	1.9	1.0	55
7............	Range R57-R58, 120 feet from R57....	2.9	10.4	3.0	58
8............	Range R66-R67, 75 feet from R67....	1.0	4.0	1.0	2/ 83
9............	Range R86-R87, 50 feet from R87....	6.0	6.5	4.0	62
Average....	....	......	....	......	58
	Ponded-channel section				
A............	Range R74-R75 (composite sample)	3.5	3.0	1.0	3/ 99
B............	Range R90-R91 (composite sample)	2.5	3.0	1.0	3/ 99
Average....	....	......	....	......	99
Average for entire reservoir........		......	....	......	4/ 63

[1]Depth to which lower end of sampler penetrated sediment.

[2]Sediment more compact than rest owing to exposure by draw-down. Not used in computing average, as it represents a negligible volume.

[3]Approximate weights based on an estimated porosity of 40 percent.

[4]Weighted average, based on volume of sediment in each section.

Table 2.--Distribution of sediment in Burlington Reservoir, Burlington, N. C.

Section	Storage capacity			Sediment		
	Original	1938	Loss	Volume	Relation to original capacity of reservoir	Relation to total sediment in reservoir
	Acre-feet	Acre-feet	Percent	Acre-feet	Percent	Percent
Lower basin (dam to range R44-R45 on Stony Creek and range R86-R87 on Deep Creek)............................	1,251.1	1,159.1	7.35	92.0	6.18	56.41
Delta section:						
Stony Creek (range R44-R45 to range R62-R63)......................	126.1	97.1	23.00	29.0	1.95	17.78
Deep Creek (range R86-R87 to range R92-R93)...........................	16.6	5.7	65.66	10.9	.73	6.68
Total delta section..............	142.7	102.8	27.96	39.9	2.68	24.46
Ponded-channel section:						
Stony Creek (range R62-R63 to head of backwater).....................	93.1	62.5	32.87	30.6	2.06	18.76
Deep Creek (range R92-R93 to head of backwater).....................	.7	.1	85.71	.6	.04	.37
Total ponded-channel section.....	93.8	62.6	33.26	31.2	2.10	19.13
Total reservoir............................	1,487.6	1,324.5	10.96	163.1	10.96	100.00

Distribution of Sediment

As shown by table 2, the combined delta and ponded-channel sections of the reservoir, representing only 16 percent of the original storage capacity, contained more than 43 percent of the total sediment in the basin. The average loss of storage capacity in these combined sections was about 30 percent as compared with a loss of 7.4 percent in the lower basin. Figure 5,A, showing cross-section areas of the original basin and of sediment deposits on the Stony Creek arm, depicts this loss graphically.

As previously mentioned, the three lake sections distinguished here are marked by comparatively uniform sedimentation conditions. The general condition in each section is shown in the three representative cross sections in figure 6. The lower basin is characterized by comparatively uniform deposition laterally, there being only a slight tendency for a thickening of the sediment blanket within the submerged channel (fig. 6,A). In contrast, the delta sections, although featuring comparatively minor deposition in the channel, are marked by heavy accumulation in the form of natural levees along one or both sides of the channel, from which there is a gradual decrease in thickness toward the banks (fig. 6,B). The representative cross section of the ponded-channel sections (fig. 6,C) illustrates the general tendency toward uniform deposition from bank to bank in this section, a condition analogous to the results of normal aggradation in an overloaded stream channel. Thus the type of deposition is observed to be radically different in each of the sections.

This distinction is borne out by the differences in volumes and thicknesses of sediment in the various sections. Figure 5, showing graphically the cross-sectional area, width of measured cross section, and average sediment thickness on each range across the Stony Creek arm, illustrates the longitudinal variations in the sediment body throughout this main arm. The striking uniformity of average thicknesses and cross-sectional areas of sediment in the lower basin is in decided contrast with the irregularities in the delta and ponded-channel sections. This is probably due primarily to the effect of strong currents prevailing in these upper reaches during high-water stages. Sediment distribution in these sections has the following points in common with that of a normal aggrading stream: (1) piling up of sediment in the straighter reaches and scouring on bends, and (2) increased lateral deposition in abnormally wide areas as compared with narrow reaches.

Variations in the maximum sediment thickness on successive ranges show a close parallelism to variations in the average thickness. Deposits in the lower basin maintain an average maximum

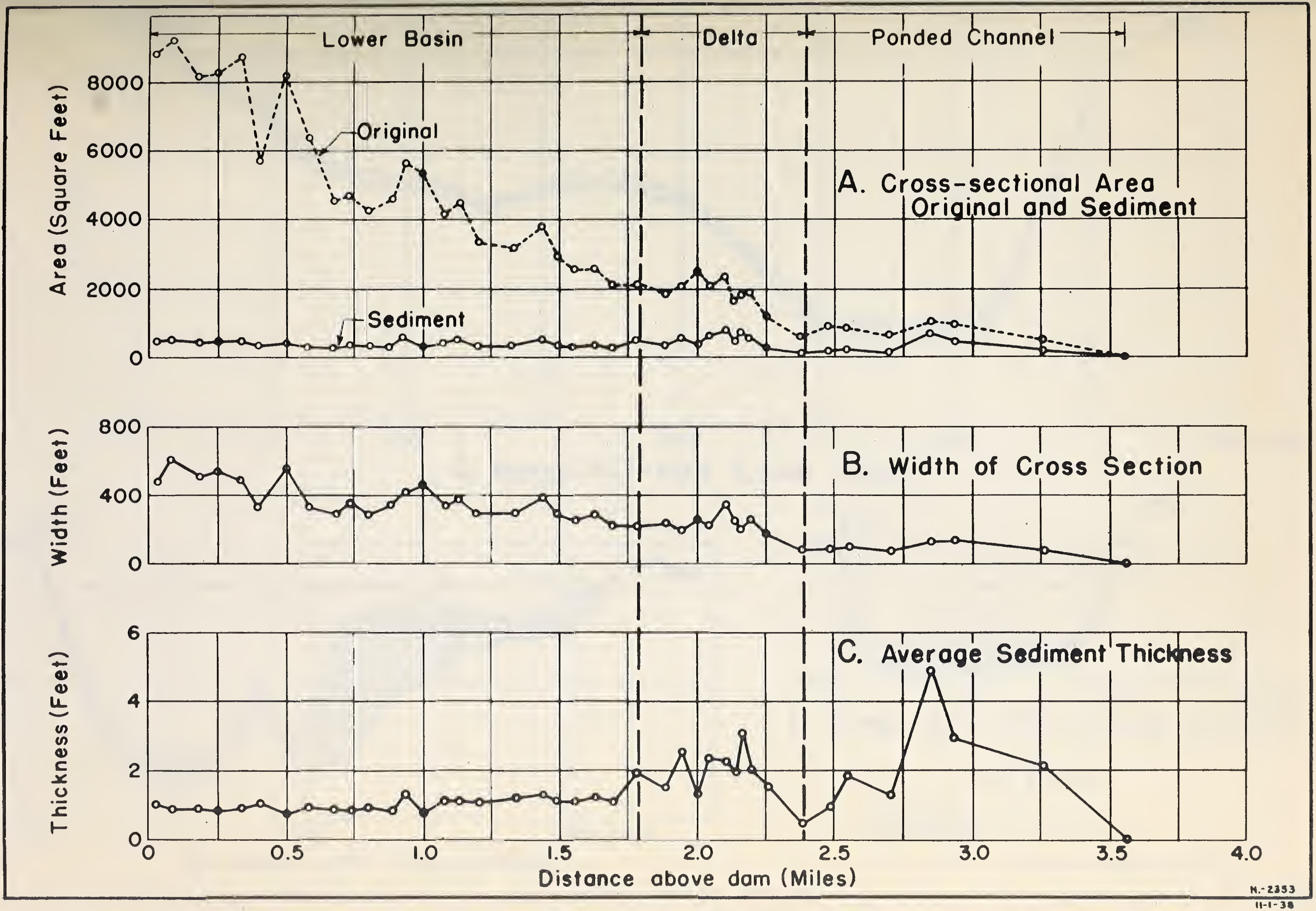

Figure 5.–Longitudinal distribution of sediment in Stony Creek Arm, Burlington Reservoir, Burlington, N.C.

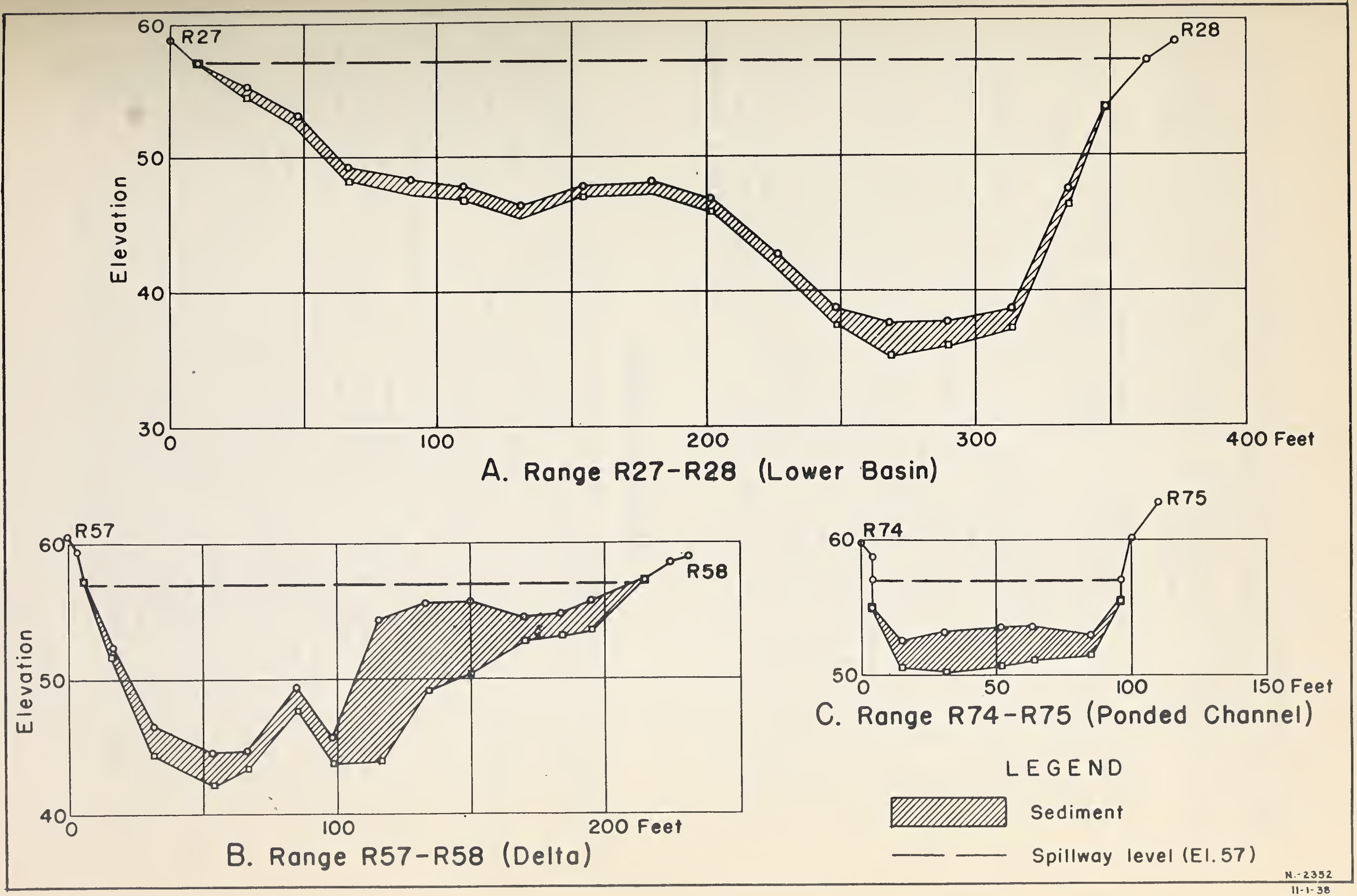

Figure 6.-Representative Cross Sections of Burlington Reservoir, Burlington, N.C.

thickness of about 2 feet rather regularly as compared with deposits in the upper parts of the lake, which range from a thin film to a bed 6 feet thick. There is, however, a concentration of sediment in the submerged channel at the mouth of the Deep Creek arm, where channel deposits reach a thickness of 3 feet.

The sections between ranges R44-R45 and R62-R63 on Stony Creek, and between ranges R86-R87 and R92-R93 on Deep Creek have been somewhat arbitrarily defined as delta areas, although they have little in common with a true delta formation as generally understood. In effect, these sections constitute areas subject to a predominantly lateral type of sedimentation, distinct from the blanket type of sedimentation in the lower basin. Sedimentation in the delta sections is strikingly similar to that in a normal aggrading stream bordered by a low flood plain subject to periodic overflow. The gradual decrease in grain size from the channel outward and the building of distinct natural levees adjacent to the channel constitute the distinguishing features of these sections. Figures 5,A and 5,B appear to indicate that the delta section is marked by a fairly rapid increase in the width and cross-sectional area of the basin. In reality this increase is due to the passage of the original stream flood plains beneath reservoir crest level.

Origin of Sediment

A fairly complete reconnaissance examination of the drainage area indicated that most of the reservoir sediment, and particularly the finer-grained fraction, has originated from rather severe sheet erosion over the greater part of the drainage area. As indicated in the discussion of erosion conditions, approximately 60 percent of the area is undergoing moderately severe sheet erosion. In addition to the sediment furnished by sheet erosion, a considerable volume originates in limited areas subject to severe to moderate gullying. Field examination indicated that most of the coarser-grained sediment originated in this manner. During the course of the reconnaissance some time was spent in tracing the source of the coarse sand and fine gravel which make up the bed load of Deep Creek and the delta at the head of the Deep Creek arm of the reservoir. By following the stream and all tributaries that showed signs of being overloaded or sanded, specific areas of gullying were found to be the ultimate source of practically all this material. Much of this gullying has occurred in road ditches and steeply sloping and unprotected road banks. Locally, unprotected borrow pits along the roads are important sources of sediment. One of these lies just north of the road on the east side of the first bridge above the dam on Stony Creek.

Wave erosion along the lake shore, where protection by vegetation is not complete, and bank cutting along the streams above the reservoir are additional but very minor factors contributing to sedimentation in Burlington Reservoir.

RELATION OF RESERVOIR SEDIMENTATION TO THE TOTAL EROSIONAL OUTPUT OF THE DRAINAGE AREA

The average annual sediment accumulation in Burlington Reservoir, as determined by the survey, was 16.3 acre-feet, equivalent to about 10.57 cubic feet per acre of drainage area. If the average dry weight of the reservoir sediment is 63 pounds per cubic foot,[5] and that of the soil in the drainage area is 97.3 pounds per cubic foot,[6] the measured rate of sedimentation indicates that the time required to remove 1 inch of soil from the entire area is about 530 years. It is evident, however, that this is a maximum figure, for it disregards two important factors; namely, (1) upstream deposition and (2) bypassing of sediment through the reservoir basin.

The approximate rate of erosion or land denudation in the drainage area can be computed on the basis of erosion maps of the Stony Creek Soil Conservation Project (NC-4) which covers 64 percent of the total drainage area, that is, the lower part lying within Alamance County (fig. 1).

Conservation mapping, which has been completed on the lower section of the drainage area, has furnished data on the extent of topsoil loss and the percentages of land under each of the erosion classifications. (See page 9.) On the assumption, substantiated by a reconnaissance examination, that the erosion conditions mapped in the project area are representative of the entire drainage area, it is possible to calculate the total volume of soil moved from place within the watershed. On the basis of an average original topsoil thickness of 8 inches, the average soil loss during the 200-year period of agricultural activity has been 3.5 inches over the entire drainage area.

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[5]See table 1, page 15.

[6]Based on the volume weights of samples from the surface and the two upper horizons of a set of three fine sandy loams (corresponding approximately to the principal soil types of this area), given by Middleton, H. E., Slater, C. S., and Byers, H. G. The Physical and Chemical Characteristics of the Soils from the Erosion Experiment Stations--Second Report. U. S. Dept. Agr. Tech. Bull. 430: 21, 1934.

These calculations indicate that the time required to remove 1 inch of soil from the entire drainage area is approximately 60 years, in contrast with the 530 years calculated on the basis of reservoir sedimentation. This calculated rate of erosion indicates that a total of 970 acre-feet of soil was removed from place in the drainage area during the life of Burlington Reservoir.

In order to account for the disparity between these calculated rates of land denudation, all possible modes of disposal of erosional debris must be considered. These are: (1) colluvial deposition at the base of slopes, (2) alluvial deposition in stream channels or on flood plains, (3) deposition in upstream reservoirs or ponds, (4) above-crest deposition adjacent to Burlington Reservoir, (5) deposition within the reservoir basin, and (6) bypassing of fine-grained sediment completely through the reservoir.

No accurate information on the volume of colluvial deposits in the drainage area is available, but a reconnaissance investigation indicated that the amount is fairly large.

Redeposited erosional debris has been mapped on approximately 6 percent of the land in the Alamance County portion of the drainage area. This 6 percent consists almost entirely of alluvial bottom lands. By taking this percentage as representative of the entire drainage area, and assuming that the average thickness of sediment in these deposits is 12 inches (probably a minimum figure), it has been calculated that approximately 200 acre-feet of sediment has accumulated on upstream bottom-land areas during the 10-year life period of Burlington Reservoir. In addition to this bottom-land sedimentation, a smaller proportion of the erosional debris, mainly the sandy fraction, has accumulated in stream channels above the reservoir. The most noticeable of these deposits, occupying a 1.5-mile reach on Stony Creek immediately above the reservoir and believed to have been deposited since the construction of the dam, contains approximately 15 acre-feet of sediment.

Deposition in upstream ponds is relatively unimportant in the drainage area. One fairly large mill pond on Stony Creek has been operated throughout the life of Burlington Reservoir. This pond, about 6 miles above the head of backwater of the reservoir, is about 30 years old and has filled to such an extent that most of the incoming sediment load is bypassed. The sediment is subject to considerable scouring during floods. In view of the low capacity-inflow ratio of the pond and the comparative rapidity with which such ponds accumulate sufficient sediment to destroy their efficiency as silt traps, it is believed that this old pond was bypassing the major proportion, or perhaps all, of the incoming sediment by the time Burlington Reservoir was completed.

Above-crest deposits adjacent to the reservoir occur somewhat sporadically from the head of backwater down to about range R53-R54 on the Stony Creek arm and to range R88-R89 on the Deep Creek arm. These deposits are mainly in the form of natural levees which vary in width from 5 to 10 feet and have an average thickness of at least 6 inches. In several places coarse modern sand at least 1 foot thick has accumulated around the base of stumps and trees. The heavy growth of vegetation (alders, willows, honeysuckle, briers, etc.) along the shores has undoubtedly encouraged this sedimentation. The total volume of these above-crest deposits is probably not more than 2.5 acre-feet.

In addition to the sediment deposited in the reservoir, a fairly large percentage of the finer-grained suspended matter is bypassed completely through the basin. This silt and clay-size debris is bypassed in three ways: (1) over the spillway, (2) through the turbine used to pump water into the city feed-line, and (3) directly into the city feed-line. Discharge of debris in varying amounts over the spillway occurs approximately 6 months out of the year, but is probably relatively unimportant except during limited periods of flood flow. The turbine is also used approximately 6 months out of the year, during which time considerable sediment is bypassed. The passage of lake water containing widely varying proportions of sediment into the city feed-line is almost constant throughout the year.

From the fairly complete set of water-consumption and turbidity records kept at the city filter plant, it is possible to derive the approximate volume of sediment removed at the settling basins. Calculations indicate that approximately 0.7 acre-foot of sediment has been removed in these basins during the life of the reservoir. On the basis of comparative discharge between the water bypassed through the turbine and that which enters the city feed-line, it is calculated that approximately 3.5 acre-feet of sediment has been bypassed through the tailrace during the life of the reservoir. In view of the lack of records on gage heights or discharge over the spillway it is impractical to attempt to calculate the volume of sediment directly bypassed. That this volume is large is indicated by rough calculatiens of the volume of sediment bypassed over the spillway in one observed 6-hour period of heavy flood flow. During this one short period an estimated minimum of 2 acre-feet of fine-grained sediment was discharged over the spillway.

To sum up briefly the available data on land denudation in the Burlington Reservoir watershed: Of a probable total volume of 970 acre-feet removed from place during the 10-year life of the reservoir, 200 acre-feet (roughly 20 percent) is estimated to have accumulated in measurable deposits on upstream bottom lands; 15 acre-feet (1.5 percent) has accumulated in the Stony Creek channel

immediately above the reservoir; 2.5 acre-feet (0.3 percent) has accumulated in above-crest deposits adjacent to the reservoir; 163 acre-feet (17 percent) has accumulated below crest within the reservoir basin, and approximately 4 acre-feet (0.4 percent) has been bypassed through the tailrace or into the city intake lines. Disregarding the probable greater porosity of these various deposits as compared with the soil in place, the sum of the above volumes leaves approximately 585 acre-feet, or 60 percent of the total soil moved from place, unaccounted for. This discrepancy is no doubt made up largely, if not entirely, by (1) colluvial deposits and (2) sediment bypassed over the spillway of Burlington Reservoir. Unfortunately no further evaluation of the actual or relative importance of these factors is possible.

It should be noted that the above figures cannot be accepted as quantitatively correct. However, it is believed that they do illustrate the relative importance and order of magnitude of the major factors involved in the disposal of erosional debris from the drainage area.

CONCLUSIONS AND RECOMMENDATIONS

Burlington Reservoir, at the time of survey, had sustained a total capacity loss of 10.95 percent, or 1.10 percent per year. This is a relatively high rate compared with many other reservoirs in the Southeastern States.

The reservoir property, owned by the city of Burlington, now extends only 5 feet from crest-level shore line. The acquisition and treatment of a wider strip of land adjacent to the lake, especially the several areas of cultivated sloping land which are subject to much sheet and rill erosion, and the borrow pit mentioned above, would seem to be a worth-while undertaking.

Prominent and probably quantitatively important sources of sediment are the various county, State, and private roads in the area. Improperly constructed road ditches, unprotected, abandoned stretches of roadway, and improperly sloped and unprotected banks in road cuts constitute a direct menace to the storage capacity of the reservoir. A very excellent demonstration of what can be done toward proper treatment of roads to minimize damage from this source is included in the soil conservation project covering part of the drainage area. Location of erosion-control work on roads is shown in figure 1. It would seem to be decidedly advisable for the city to encourage in every possible manner the proper planning, construction, and maintenance of roads.

The present silting rate is, however, so directly connected with the widespread sheet and gully erosion that the ultimate expansion of proper erosion-control practices to cover the entire drainage area offers the major hope of solving the silting problem. Much of the land within the Stony Creek Soil Conservation Project boundaries in Alamance County has been adequately treated with proper scientific erosion-control measures, and this treatment will probably effect a substantial decrease in the rate of sediment output from the areas covered. The ultimate treatment of all such eroding lands is highly desirable, not only for its value to the land, but as a measure of protection of downstream resources, including the reservoir.

Methods of erosion control advocated by project officials include:

(1) Retirement of steeper slopes from cultivation to permanent or semipermanent vegetation using grasses, kudzu, lespedeza sericea, or trees.

(2) Introduction of more close-growing crops in cropping systems; that is, annual lespedeza, small grains, and winter cover crops.

(3) Construction of the Nichols- or Mangum-type terraces with carefully planned vegetative outlets.

(4) More extensive use of strip cropping either with or without terraces. In some places broad rotated strips, and in others narrow vegetative strips above flow line of terraces, especially on tobacco land, should be used.

(5) Contour tillage should be practiced.

(6) Increased use of contour furrows in pasture land.

(7) Adequate treatment of all permanent pastures with plant-food materials - manure, fertilizer, and lime.

In conjunction with an attack on sediment production at its ultimate sources, it would appear highly desirable to seek some feasible method of controlling the sediment that is already in transit down the drainageways. The reconnaissance examination has indicated that a comparatively large volume of sediment has been temporarily deposited in and immediately adjacent to stream channels in the drainage area. All this sediment is readily susceptible to further downstream movement and will ultimately displace

reservoir storage. Possible solution of this problem would seem to lie either in engineering structures or in vegetative control, seeking either to stabilize such deposits in their present position or to encourage their distribution and stabilization over areas of worthless land above the reservoir.

The quantitative results of the detailed sedimentation survey of Burlington Reservoir are summarized in the following tabulation:

Summary of data on Burlington Municipal Reservoir, Burlington, N. C.

	Quantity	Unit
Age[1]	10	Years
Watershed area[2]	105.2	Sq. miles
	67,334	Acres
Reservoir:		
Area at spillway stage:		
Original	137	Acres
At date of survey	136	Acres
Storage capacity to spillway level:		
Original	1,488	Acre-feet
At date of survey	1,325	Acre-feet
Capacity per sq. mile of drainage area:[2]		
Original	14.14	Acre-feet
At date of survey	12.60	Acre-feet
Sedimentation:		
Total sediment	163	Acre-feet
Average annual accumulation:		
From entire drainage area	16.3	Acre-feet
Per 100 sq. miles of drainage area[3]	15.5	Acre-feet
Per acre of drainage area:[3]		
By volume	10.57	Cubic feet
By weight[4]	0.33	Ton
Depletion of storage:		
Loss of original capacity:		
Per year	1.10	Percent
To date of survey	10.95	Percent

[1]Storage began in June 1928; date of survey, April 16 - May 21, 1938.

[2]Including area of lake.

[3]Excluding area of lake.

[4]Based on an average dry weight of 63 pounds per cubic foot, as determined from 11 undisturbed samples (table 1).

Figure 4


U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
BURLINGTON MUNICIPAL RESERVOIR
STONY CREEK
ALAMANCE COUNTY
NORTH CAROLINA
SEDIMENTATION SURVEY OF APRIL 19 TO MAY 20, 1938
200 0 200 400 600 800
LEGEND
Triangulation Station
Reservoir Segment Number
Thalweg of Original Stream Channels
Plane table Station
Area Silted Above Original Spillway Crest
Stony Creek
Deep Creek
DAM
True North